THE PLANT DISEASE REPORTER

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PAPERS PRESENTED AT THE COTTON DISEASE COUNCIL AT HOUSTON, TEXAS, DECEMBER 16, 1958

Supplement 259

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Crops Research Division serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

THE PLANT DISEASE REPORTER

MYCOLOGY AND PLANT DISEASE REPORTING SECTION

Crops Protection Research Branch — Plant Industry Station, Beltsville, Maryland

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PROGRESS WITH PROBLEMS IN COTTON DISEASE CONTROL[1]

Albert L. Smith[2]

Cotton disease loss estimates show a year to year variation from 10 to 14 percent or 1 1/2 to 2 million bales during the 6-year period, 1952 to 1957. The money value of this loss in seed and lint in recent years averaged about 300 million dollars. The reduction of these overall losses and elimination of serious losses to individual growers is a real challenge to plant pathologists and other scientists.

To define the problems in cotton disease control, surveys of disease losses have been made annually in 14 major cotton-producing States since 1952. P. J. Leyendecker, 1952 to 1956; and Harlan E. Smith, 1956 to the present time, as chairman of the Cotton Disease Losses Committee of the Cotton Disease Council, assembled and compiled the estimates that were the cooperative efforts of cotton State pathologists and agronomists. The loss estimates have been published annually in the Plant Disease Reporter and summaries were published for the 1952 to 1955 and 1952 to 1956 periods (1, 2). Loss data reported here cover the 1952 to 1957 period.

DISEASE LOSS ESTIMATES

The relative importance of the seven major cotton diseases is illustrated in Figure 1, by the average annual loss in bales resulting from each disease.

Seedling diseases, boll rots, and bacterial blight, which are found from coast to coast, are of greatest importance. Verticillium wilt, root-knot, Fusarium wilt, and root rot are diseases of more limited distribution. Several diseases causing smaller losses are not reported here.

REGIONAL DISTRIBUTION OF DISEASE LOSSES

Disease losses are grouped according to the three major cotton-producing regions, which are largely determined by climate and soil type. These regions are the Southwestern, composed of California, Arizona, New Mexico, Texas, and Oklahoma; the Mississippi Valley, with Louisiana, Mississippi, Arkansas, Missouri, and Tennessee; and the Southeastern, composed of Alabama, Georgia, South Carolina and North Carolina. The relative importance of losses caused by major diseases for the three regions is shown in Table 1. The data indicate that losses are slightly higher in the Southeastern region, 9.09 percent, as compared with the Southwestern region, 8.96 percent, and the Mississippi Valley, 8.63 percent. The greater losses in the Southeastern region may be partially attributed to effects of environment.

Seedling disease losses predominate in all three regions. The Southwest is characterized by high losses from root rot, Verticillium wilt, and bacterial blight, with nematodes and boll rots of secondary importance (Table 1). In the Mississippi Valley, Fusarium wilt and boll rots are of major importance, with Verticillium wilt and bacterial blight of secondary rank. The major causes of loss in the Southeast are boll rots and nematodes, followed by Fusarium wilt and bacterial blight.

Cotton disease losses have paralleled the westward shift in cotton production. The percentages of total production for the three regions are as follows: Southwestern 45.1, Mississippi Valley 33.5, and Southeastern 21.4. The corresponding percentages of total disease losses from eight diseases for the three regions are 45.5, 32.4, and 22.0, respectively.

In the Mississippi Valley region the overlapping distribution of eastern and western types of diseases sometimes creates a severe disease situation, best illustrated by the loss estimates for Missouri in 1957 (Table 2). Root rot was the only major disease not prevalent in Missouri. This 1957 disease loss report of 32.6 percent was the highest loss estimate in the 83 State reports made during the period from 1952 to 1957.

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[1] Paper presented to the Cotton Disease Council, Houston, Texas, December 14 and 15, 1958.

[2] Plant Pathologist, United States Department of Agriculture, Agricultural Research Service, Crops Research Division, Cotton and Cordage Fibers Research Branch, Cooperative with Agronomy and Soils Department, Alabama Polytechnic Institute, Agricultural Experiment Station, Auburn, Alabama.

Table 1. Average annual loss, in bales, percentage reduction in yield, and dollar value, resulting from major cotton diseases in 14 States; regional and United States summary for the 6-year period 1952 to 1957.

Disease causing loss	Southwestern		Mississippi Valley		Southeastern		United States totals		
	1000 bales	Percent	1000 bales	Percent	1000 bales	Percent	1000 bales	Percent	Million dollars[a]
1. Seedling diseases (Rhizoctonia, Pythium, etc.)	175	2.12[b]	131	2.15	96	2.44	402	2.20	73
2. Boll-rots (Glomerella, Diplodia, etc.)	63	0.76	125	2.05	87	2.22	275	1.51	50
3. Bacterial blight (Xanthomonas malvacearum)	139	1.69	51	0.84	33	0.84	223	1.22	41
4. Verticillium wilt (Verticillium albo-atrum)	142	1.72	52	0.85	2	0.05	195	1.07	35
5. Root-knot nematode (Meloidogyne spp.)	70	0.85	34	0.56	87	2.22	192	1.05	35
6. Fusarium wilt (Fusarium oxysporum f. vasinfectum)	3	0.04	131	2.15	46	1.17	180	0.99	33
7. Root rot (Phymatotrichum omnivorum)	144	1.75	tr	tr	0	0	144	0.79	26
8. Ascochyta blight (Ascochyta gossypii)	3	0.04	2	0.03	7	0.18	12	0.07	2
Totals, lost	739	8.96	526	8.63	358	9.09	1,623	8.88	295
Totals, harvested	7,503		5,567		3,570		16,640		
Totals, harvested and lost	8,242		6,093		3,928		18,263		

[a] Lint calculated at $160 per bale and seed at $55 per ton.

[b] Percentages calculated from total bales harvested and lost, divided into bales lost.

Table 2. Cotton losses in Missouri for 1957, a year of maximum loss for any State during the survey period 1952 to 1957.

Disease causing loss	Reduction in yield: Percent	Reduction in yield: Number of bales	Value of seed and lint (1000 dollars)
1. Boll rots	11.0	35,090	6,246[a]
2. Fusarium wilt	8.0	25,520	4,543
3. Bacterial blight	7.0	22,330	3,975
4. Verticillium wilt	2.5	7,975	1,420
5. Root-knot nematode	2.0	6,380	1,136
6. Seedling diseases	1.1	3,509	625
7. Ascochyta blight	1.0	3,190	568
Total losses	32.6	103,991	18,510
Harvested		215,000	38,270

[a] Lint calculated at $160 per bale and seed at $45 per ton.

Table 3. Average annual cotton disease losses, 1952 to 1957, from diseases for which (a) disease resistance, or (b) cultural practices, chemicals and other control measures, might be utilized or developed.

Disease causing loss	Percentage reduction in yield	Losses in bales (1000 bales)	Losses in crop value (million dollars)	Percentage of total disease loss
(a) Control by disease resistance				
1. Bacterial blight	1.22	223	41	13.7
2. Verticillium wilt	1.07	195	35	12.0
3. Root-knot nematode	1.05	192	35	11.8
4. Fusarium wilt	0.99	180	33	11.1
Totals	4.33	790	144	48.7
(b) Control by cultural practices, chemicals, etc.				
1. Seedling diseases	2.20	402	73	24.8
2. Boll-rots	1.51	275	50	16.9
3. Root-rot	1.75	144	26	8.9
4. Ascochyta blight	0.07	12	2	0.7
Totals	5.53	833	151	51.3

THE METHODS OF DISEASE CONTROL

Methods of disease control may be divided into two categories, (a) breeding for resistance, and (b) control by cultural practices, chemicals, and other methods (Table 3). Bacterial blight, Verticillium wilt, root-knot, and Fusarium wilt, which together account for 48.7 percent of the estimated losses, can be controlled most satisfactorily by developing resistant varieties. Seedling diseases, boll rots, root rot, and Ascochyta blight, which cause 51.3 percent of the losses, are controlled at present by methods other than breeding. These categories are not strictly defined, as root-knot nematode at present is partially controlled with soil fumigants. Seedling diseases may some day be partially controlled by developing cold-tolerant and disease-resistant varieties.

PROGRESS IN DISEASE CONTROL

Seedling diseases, which account for approximately 25 percent of the total cotton disease losses, constitute a highly complex problem involving seed quality, soil texture, climate, soil- and seed-borne pathogens, fungicides, machines, and the vagaries of human nature, spread over a geographical expanse of 3000 miles. Progress in controlling seed-borne anthracnose has been the most spectacular development. Emergence of seedlings has been improved about 30 percent throughout the rainbelt. This phase of the work is essentially complete now, with the widespread adoption of fungicidal seed-treatment throughout the cotton belt. The major remaining seedling losses are attributed to soil-borne pathogens, such as Rhizoctonia, Pythium, Fusarium, and others. Excellent progress is being made in the development of satisfactory fungicides for in-furrow application. However, only about 200,000 acres are currently being planted with in-furrow fungicide treatments. The more basic problems, concerning the pathogens involved, seed deterioration, cold tolerance, and specificity of fungicides, are under investigation and further progress in seedling disease control is anticipated.

Serious boll-rot losses are largely dependent on weather conditions at the critical opening period. Boll rots account for 17 percent of the total disease loss. Probably this loss will not be measurably reduced in the near future. However, some decrease may be anticipated from the widespread development of bacterial blight-resistant varieties. Improvement of insecticides leading to reduction in number of insect wounds would also decrease boll-rot losses moderately.

Bacterial blight offers the best opportunity of any cotton disease for complete control in the immediate future. Although the blight breeding work has been under way for less than 20 years the varieties Acala 1517 BR, Austin, Blightmaster, and Rex, all resistant to Race 1, have been released. The appearance and rapid buildup of Race 2 of the blight pathogen has nullified a part of the value of these early releases. However, the importation of B_2, B_3 from Knight's Sudan collection by Luther Bird of Texas A & M College, and their crossing into a number of commercial types, has provided a means for developing varieties resistant to both Race 1 and 2. Within the near future, new blight-resistant varieties will be widely available and blight losses thus markedly reduced, if not eliminated.

Verticillium wilt is a relatively new disease of cotton but it has spread rapidly. Losses fluctuate widely with temperature and rainfall. No major breakthrough in locating resistant genes has been accomplished. However, each year some improvement in Verticillium tolerance of varieties has been reported from several locations. Evidence indicates that resistance is controlled by minor genes, consequently progress will be slower than with diseases where fewer genes are involved.

Cotton root-knot nematode losses constitute a major problem in the Southeastern region. These losses have only recently been recognized because of the nature of the wilt-nematode complex. The widespread planting of Fusarium-resistant varieties has reduced wilt losses, whereas rootknot losses remain. Root-knot losses are of sufficient importance in the Southwestern and Mississippi Valley regions to indicate that all commercial varieties need improvement for resistance. Clevewilt 6 and Auburn 56 are Upland commercial types with superior root-knot tolerance. Sources of high resistance are available in wild types of Gossypium barbadense and G. hirsutum. Root-knot resistance, being polygenic and recessive, will be difficult and time-consuming to transfer to commercial types.

Progress in the control of Fusarium wilt is illustrated by the percentage of total acreage planted (3) to resistant varieties (Fig. 2). The reduction in loss by use of resistant varieties in the Southeastern region is shown in the estimates (Table 1). At the present time, the greatest losses from Fusarium wilt are reported in the Mississippi Valley, where the disease became established relatively late and is still increasing in severity. Locally adapted resistant varieties are not yet available. Further progress in reducing wilt losses in the Southeastern region can be made only by improving the nematode resistance of varieties grown on wilt-infested soils. The importance of root-knot nematode tolerance in reducing wilt losses was amply demonstrated in the wide testing of the root-knot tolerant variety Auburn 56.

Cotton root-rot has caused some abandonment of cotton culture in certain areas, particularly the Blackland Prairies of Texas. Although biological control of root-rot through crop rotation was developed, difficulty was encountered in obtaining grower acceptance of the practice. At the present time, only limited progress can be reported in the control of root-rot.

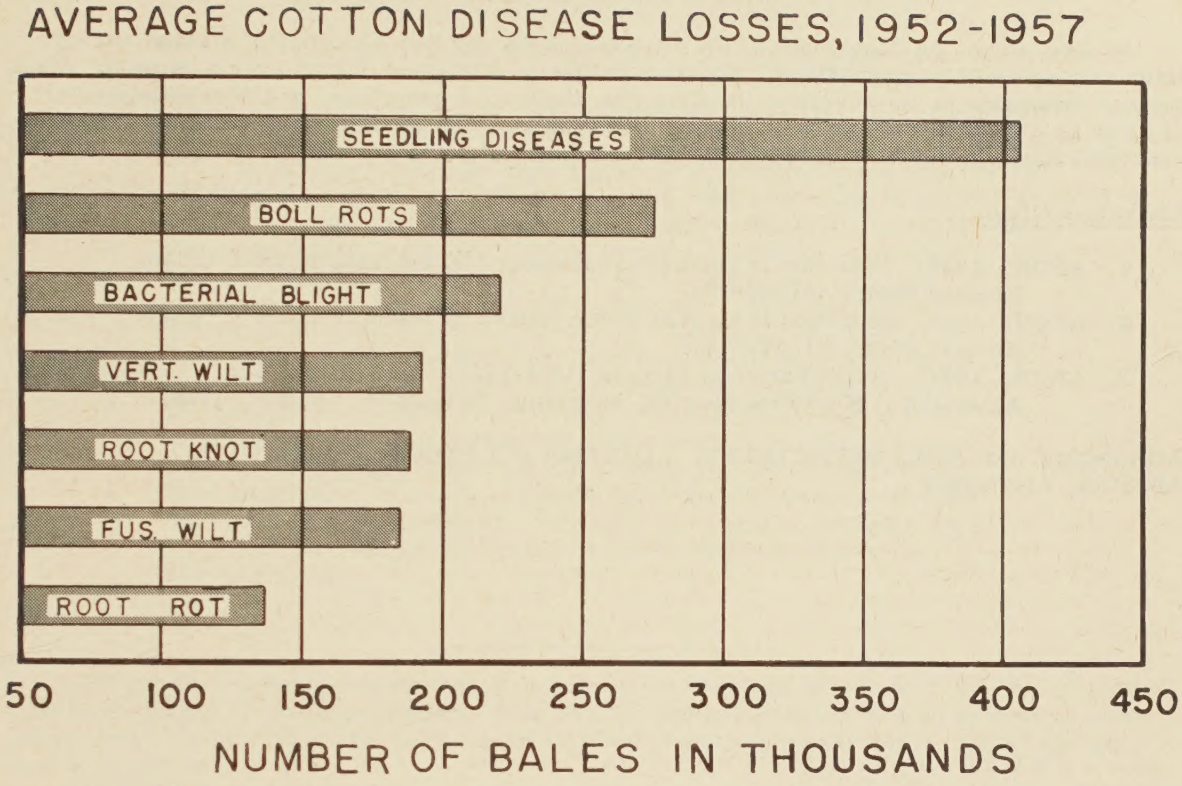

FIGURE 1. Reduction in bales from full yield caused by major cotton diseases, averages for the 6-year period 1952 to 1957. United States.

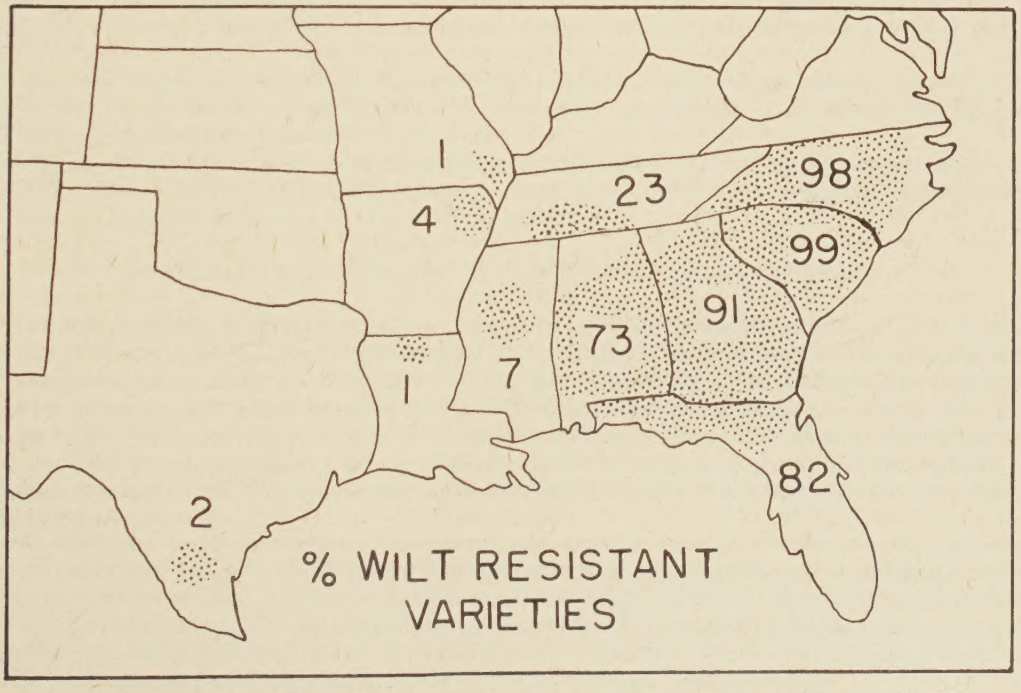

FIGURE 2. Percentages of total cotton acreage planted to Fusarium wilt-resistant varieties in States where wilt is established, 1958.

CONCLUSION

In conclusion, the importance of the continued gathering and tabulation of disease survey information should be emphasized. Accurate estimates of disease losses over a period of years become invaluable to the worker in the field, the director of programs, and the administrator of funds as a yardstick for measuring progress. Pathologists working with cotton have the responsibility to make the most accurate disease loss estimates possible.

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AGRONOMY AND SOILS DEPARTMENT, ALABAMA POLYTECHNIC INSTITUTE, AUBURN, ALABAMA

VALUE OF COTTON SEEDLING DISEASE CONTROL

Dow D. Porter, L. S. Bird and N. B. Smith[1]

Abstract

In-furrow fungicides were applied at planting to control the seedling disease complex of cotton. Plots where the disease was controlled were compared with control plots to determine the loss caused by seedling disease. Under disease conditions severe enough to cause reduced stands a net return of $27 per acre was measured where the disease was controlled. When disease conditions were not severe enough to cause reduced stands but did cause root injury a net return of $4 per acre was measured. Also where the disease was controlled the crop was earlier than where the disease was present. For a 2-year period an average net return of $15 per acre was obtained where replanting was not necessary and an average of $20 per acre where replanting would have been necessary, by using in-furrow fungicide applications for cotton seedling disease control. The tests were conducted under dryland conditions where the average yield is about two-thirds of a bale per acre.

The seedling disease complex of cotton causes a yield loss of at least 2.5 bales for every 100 bales ginned in the United States. It is a major disease which is caused by several soilborne fungi, among which the more important are Rhizoctonia solani Kuehn, Fusarium spp., and Pythium spp.

The seedling disease complex may be subdivided into four phases: seed rot, seedling root-rot, pre-emergence damping-off, and post-emergence damping-off. Seed rot may be controlled by proper seed treatment with any one of the approved materials. Seed treatment alone has very little, if any, effect on controlling seedling root-rot, pre-emergence or post-emergence damping-off. The zone of protection conferred by the seed protectant is too limited to prevent infection after rupture of the seed coat. Efforts have been made to protect the seedling from the seed zone to the soil surface by mixing fungicides into the covering soil at planting. This method, which proved effective, is recommended for use in controlling the seedling disease complex (1).

In-furrow fungicide application has provided a tool for evaluating losses caused by the disease. Under field conditions the disease is controlled by fungicides and these plots are compared with plots where the disease is not controlled.

In-furrow tests have been conducted at the U. S. Cotton Field Station, Greenville, Texas since 1956. The stand results and methods of application have been reported elsewhere (1, 2). Yield data were taken from the 1957 and 1958 tests.

RESULTS OF IN-FURROW FUNGICIDE APPLICATION TESTS

The results of the 1957 test are given in Table 1. The fungicide mixtures of 1.5 pounds captan plus 2 pounds zineb plus 1.5 pounds PCNB, 3 quarts nabam plus 0.5 quarts Ceresan 100, and 2 pounds Omadine 1563 plus 3 pounds PCNB gave an average yield 32 percent higher than the yield for the control. Allowing $6 per acre for the cost of applying the chemicals, the net return for controlling cotton seedling disease was $27 per acre. Increased yields tended to be associated with increased stands due to disease control. The one exception was nabam, which maintained a stand of 26,000 plants per acre but resulted in a yield that was lower although not significantly so.

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[1] Agronomist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Greenville, Assistant Professor, Texas Agricultural Experiment Station and Agent, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, College Station, and Agricultural Aid, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Greenville, Texas, respectively.

Table 1. Yield data for 1957 Greenville test-1 for evaluating fungicides mixed with the covering soil for cotton seedling disease control.

Fungicides	Rates per acre	Final stand per acre [a]	Yield, seedcotton per acre (pounds)	Yield value per acre [b] (dollars)	Percent gain over control [c]
Captan+Zineb+PCNB	1.5#+2#+1.5#	27	1258	138	35
Nabam+Ceresan 200	3 qts.+0.5 qts.	19	1219	134	31
Omadine 1563+PCNB	2#+3#	18	1205	133	30
Vancide 51	4 qts.	14	1126	124	22
PCNB+Captan+Omadine 1563	2#+2#+1#	14	1120	123	21
Nabam	4 qts.	26	1115	123	21
Captan+PCNB+Ceresan 200	2#+2#+0.25 qt.	14	1070	118	16
Control	--	6	927	102	--
L.S.D. .01		9	256		
L.S.D. .05		6	191		

[a] In thousands of plants.

[b] Based on 11 cents per pound for seedcotton.

[c] The top three treatments have an average gain over the control of 32%. For a cost of $6 per acre a net return of $27 per acre in yield was obtained. These and other factors such as not having to replant and the fact that replanted areas around the test area yielded less than the test control point out the importance of seedling disease control.

Table 2. Stand, yield and root data for the in-furrow fungicide test conducted at the U. S. Cotton Field Station, Greenville, Texas. 1958.

Fungicides	Rates per acre	Stand [a]	Total yield [b]	Yield [b] first harvest	Yield [b] second harvest	First harvest, percent of total	Percent healthy roots	Return per acre [c] (dollars)
Captan+Phaltan	2#+2#	46.2	839	305	534	36.4	80	62.88
Maneb+Ceresan 100	3#+0.5 qt.	39.8	821	259	561	31.5	82	61.14
Captan+PCNB	2#+2#	43.0	809	287	523	35.4	77	60.36
Nabam	4 qts.	41.5	799	255	546	31.8	74	59.30
Maneb	5#	50.7	795	272	523	34.2	74	59.18
Captan+PCNB+Zineb+Ca Cl_2	1.5#+1.5#+2#+10#	45.0	788	238	550	30.2	69	58.37
Captan+PCNB+Thiram	1.5#+1.5#+1.5#	38.5	787	216	571	27.4	72	58.12
Captan+PCNB+Zineb	1.5#+1.5#+2#	53.7	777	261	516	33.6	77	57.70
Acti-dione+PCNB+$FeSO_4$	3+11.43+3.75 ozs.	29.0	767	206	561	26.9	81	56.48
Nabam+Ca Cl_2	4 qts.+10#	37.8	761	223	539	29.2	70	56.11
Captan+PCNB+Zineb+G.A.	1.5#+1.5#+2#+0.2 gm.	34.3	739	257	481	34.8	77	54.73
Control	--	39.7	698	154	546	21.9	67	55.61
Control, replant	--	54.8	660	23	637	3.5	97	46.67
L.S.D. .01		13.3	91	73	70	--	--	--
L.S.D. .05		10.0	69	55	52	--	--	--

[a] Average number of seedlings per 26.2 row feet.

[b] Pounds seed cotton per acre.

[c] Where the gross return is adjusted for harvesting, replant and treatment cost. Initial planting, cultivating and insect control costs were not considered. Return value is based on 11 cents per pound for seed cotton.

FIGURE 1. Root systems of plants from treated plots on right and from the control plots on left. Branching from the main stem occurred closer to the soil line on plants from the treated plots.

The results of the 1958 experiment are given in Table 2. In this test a replant control was obtained by making a planting 3 weeks after the main test planting. The test was planted April 25 and the replant control was planted May 14. The disease was not severe enough to cause real differences in stand. There was a definite trend for the better treatments to give higher total yields than the controls. All treatments gave a significantly higher yield than the controls in the first harvest. The replant control gave the higher yield in the second harvest. The second harvest yields for the treatments and the regular control were about the same. The treatment plots tended to be about 10 percent earlier than the regular control and about 28 percent earlier than the replant control.

The root systems of the plants were examined. There was a trend, although not a significant one, for the plants in the treated plots to have healthier root systems than the regular control. Plants from the replant control definitely had healthier roots. A comparison of the root systems is shown in Figure 1.

The chemical treatments gave about a $4 per acre net return over the regular control and a $13 per acre net return over the replant control.

DISCUSSION

In-furrow fungicide application at planting for cotton seedling disease control not only helps to maintain adequate uniform stands but produces a final stand composed of seedlings with healthier root systems. Seedlings with healthy root systems grow off faster than seedlings with damaged root systems. As shown by the 1958 test results this gives an earlier crop. Where the necessity for replanting is avoided through disease control the crop is considerably earlier, as shown by comparing the regular and replant controls.

For the 2-year period at the Greenville station, an average increase in income per acre by controlling seedling disease amounted to about $15 per acre where replanting was not necessary and about $20 per acre where replanting would have been necessary. The average yield for the 2-year period was about two-thirds of a bale per acre. Therefore, this amounts to a 15 to 20 percent increase in income by controlling seedling disease.

The seedling disease situation on the Greenville station during 1957 and 1958 was typical of the Greenville, Corsicana, Dallas, and McKinney areas. If seedling disease had been controlled

by in-furrow fungicide application the cotton farmers in the area would have had an additional $15 to $20 per acre income. Therefore, the growers and the general agricultural business of the area would have been much better off financially. This is an area where cotton seedling disease is a problem 4 out of every 5 years.

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TEXAS AGRICULTURAL EXPERIMENT STATION, AND UNITED STATES DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE

POTASSIUM GIBBERELLATE AND OTHER SEED TREATMENTS FOR CONTROLLING COTTON SEEDLING DAMPING-OFF[1]

J. B. Sinclair, L. L. McCormick, D. R. Melville,
J. Y. Oakes, L. W. Sloane and D. Walters[2]

Abstract

Potassium gibberellate, Panogen (methyl-mercury dicyandiamide), Dow 9-B (zinc 2,4,5-trichlorophenoxide), and five Dow experimental seed treating chemicals of unknown composition were tested for ability to control cotton seedling damping-off. In four field tests no advantages were noted from treating cotton seed of three varieties with potassium gibberellate. There was a general tendency toward decrease in stand from seed treatment with potassium gibberellate, and in one case this treatment gave a stand significantly below that of the nontreated check. Panogen gave significantly higher stands when compared with the nontreated check. No significant differences were found between the stands from seed treated with Dow 9-B and nontreated seed. No significant differences were found between any of the Dow chemicals of unknown composition and the nontreated check, except chemical number 2 in a single test. In a greenhouse test potassium gibberellate used as an in-the-furrow treatment reduced pre-emergence damping-off significantly but showed no post-emergence disease control.

INTRODUCTION

Gibberellic acid and its derivatives, though known for over 20 years, have been intensively studied in the United States only within the last few years (4). This plant hormone induces early seed emergence and accelerates the growth of many vegetable and ornamental plants. It was thought that cotton seed treated with the potassium salt of gibberellic acid might increase emergence of cotton seed under cool, wet conditions, as well as stimulate the growth of cotton seedlings. The rapid growth might prevent or decrease the incidence of cotton seedling damping-off under field conditions. Four field trials and a greenhouse test were carried out in the spring of 1958 to test the effects of potassium gibberellate and other seed treating materials on cotton seedling damping-off.

The chemicals tested were: the potassium salt of gibberellic acid (P. G.), Panogen (methyl-mercury dicyandiamide), Dow 9-B (zinc 2,4,5-trichlorophenoxide), and five Dow experimental seed treating chemicals of unknown composition.

FIELD TRIALS

The field trials were located at the Northeast Louisiana Experiment Station, St. Joseph, and the Red River Valley Experiment Station, Curtis. The plots were completely randomized in replicated blocks. The first test at St. Joseph used reginned Deltapine Smoothleaf seed treated with P. G.; Dow 9-B; Dow seed treatments 2, 6, 7 and 9; and a nontreated check. The second test consisted of four treatments: P. G.; Panogen, P.G. plus Panogen; and a nontreated check. Reginned Stardel cotton seed was used. The first test at Curtis used reginned Deltapine Smoothleaf seed treated with P. G.; Dow 9-B; Dow seed treatments 2, 6, 7, 8, and 9; and

[1] Appreciation is expressed to Dr. A. G. Plakidas, Plant Pathologist, Louisiana Agricultural Experiment Station, and Dr. D. C. Neal, Pathologist, United States Department of Agriculture, Agricultural Research Service for reading the manuscript and helpful suggestions; to the Dow Chemical Company for providing treated Deltapine Smoothleaf cotton seed; and to Merck and Company for samples of potassium gibberellate (Gibrel).

[2] Assistant Plant Pathologist, Assistant Agronomist, Assistant Agronomist, Agronomist, Assistant Agronomist, and Research Associate, respectively, of the Louisiana Agricultural Experiment Station.

a nontreated check. The second test at Curtis used reginned Deltapine 15 cotton seed treated with P. G., Panogen, P. G. plus Panogen, and a nontreated check. P. G. was applied as a dust at the time of planting at the rate of 1 gram active ingredient to 100 pounds of seed; Dow 9-B at 3 ounces per 100 pounds of seed; and Panogen at 3 ounces per 100 pounds of seed. The tests at both locations consisted of two-row plots. Stand counts were taken on 100 feet of row for each treatment 2 weeks after planting at St. Joseph and 3 weeks after planting at Curtis.

FIELD RESULTS

Stands of cotton were generally poor because of relatively low seed viability and cool, wet weather conditions. In both locations seedling damping-off was marked throughout all plots. At St. Joseph, cotton seed treated with Panogen alone gave a significantly higher stand than seed treated with a combination of P. G. plus Panogen, but no significant difference was noted between the same treatments at Curtis. However, the latter combination at Curtis tended to give a lower stand count (Table 1). There was no significant difference between seed treated with P. G. and the nontreated plot, although the Curtis test showed that P. G.-treated seed

Table 1. Stand count means, based on 100 feet of row, from cotton seed treated with Panogen and potassium gibberellate (P. G.) alone or in combination, at location indicated, 1958.

Treatment	Means	
	St. Joseph	Curtis
P. G.	82	43
Panogen	176	140
P. G. plus Panogen	121	134
Nontreated	80	63
LSD .05	34	31
.01	48	42

Table 2. Stand count means, based on 100 feet of row, from reginned Deltapine Smoothleaf cotton seed treated with potassium gibberellate (P. G), Dow 9-B, and five Dow experimental seed-treating chemicals at Curtis and St. Joseph, 1958.

Treatment	Means	
	Curtis	St. Joseph
Dow 9-B	191	111
P. G.	153	86
Experimental Chemical No. 2	181	133
No. 6	102	122
No. 7	137	125
No. 8	138	
No. 9	141	
Nontreated check	161	119
LSD .05	ns	9
LSD .01	ns	12

tended to have a lower stand count. Differences in these tests may be due to different soil types and varieties. Reginned Stardel was used at St. Joseph and reginned Deltapine 15 at Curtis.

Deltapine Smoothleaf variety was used throughout the second series of tests at both locations. There was no statistically significant difference between seed treatments at the Curtis plot, but the stand resulting from seed treated with P. G. was considerably lower than that in the nontreated plot or plots treated with Dow 9-B or experimental treatment number 2. At St. Joseph the stand resulting from seed treated with P. G. alone was significantly lower than the stand in either of the other seed treatment plots or the nontreated plot (Table 2).

GREENHOUSE TESTS

A program of screening various chemicals for controlling Rhizoctonia damping-off of cotton seedlings under field and greenhouse conditions has been started (2, 3). P. G. was included in this screening program, along with various fungicides and antibiotics, as a liquid in-the-furrow treatment (3). Reginned Deltapine 15 cotton seed previously treated with Dow 9-B was used.

The greenhouse test was run in flats, using sterilized field soil inoculated with an isolate of Rhizoctonia solani Kuehn. Fungicides were applied at the time of sowing, at the rates of 5 pounds per acre for wettable powders and 4 quarts per acre for the liquids. Combined fungicides were applied at equivalent rates. P. G. was applied at a concentration of 50 ppm. Inoculated-nontreated and noninoculated-nontreated plots served as controls. All treatments were replicated seven times with 50 Deltapine 15 cotton seeds per replicate. Emergence counts and the number of seedlings showing damping-off symptoms were taken approximately 2 weeks after the sowing and treatment date. These figures were used to determine the percentage of healthy plants surviving from 50 seed sowed.

GREENHOUSE RESULTS

The emergence mean from seed treated with P. G. was significantly lower than from seed treated with PCNB plus captan, PCNB plus nabam, and the nontreated-noninoculated check. No statistically significant difference in emergence was found between P. G. treated seed and the PCNB plus dichlone treatment (Table 3). However, emergence from the P. G. treated seed was significantly above that from the nontreated-inoculated check. P. G. gave no disease con-

Table 3. Means of indicated treatments for emergence (E) and disease (D), and percentage of surviving healthy cotton seedlings from 50 seed (MH) when grown in sterilized field soil inoculated with an isolate of Rhizoctonia solani under greenhouse conditions, 1958.

Treatment	Means		
	E	D	MH
PCNB plus captan	37	5.7	63
PCNB plus nabam	40	2.4	76
PCNB plus dichlone	33	18.0	29
Potassium gibberellate (P.G.)	26	25.7	0
Nontreated-inoculated check	4	4.0	0
Nontreated-noninoculated check	39	0.0	77
LSD .05	12	1.7	3
LSD .01	16	2.2	4

trol, as indicated by the highest mean for the disease index and by absence of surviving healthy plants.

SUMMARY AND CONCLUSIONS

Field tests showed that there were no advantages gained by treating cotton seed of three varieties with potassium gibberellate for controlling cotton seedling damping-off. There was a general tendency for a decrease in stand from seed treated with potassium gibberellate and in one case potassium gibberellate gave a stand significantly below that of the nontreated check.

In a single greenhouse test, using potassium gibberellate and other chemicals as an in-the-furrow treatment, potassium gibberellate tended to reduce pre-emergence damping-off significantly, but showed no post-emergence disease control. These latter results are in general agreement with the findings of Bradford and Ewing (1).

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LOUISIANA AGRICULTURAL EXPERIMENT STATION

COTTON SEED TREATMENT TRIALS IN CALIFORNIA, 1954-1958 WITH SPECIAL REFERENCE TO SPECIFIC FUNGICIDES

L. D. Leach[1], R. H. Garber[2], and W. H. Lange[3]

Abstract

Uniform seed treatment trials conducted in the cotton-producing areas of California during 1953, 1954 and 1955 showed that several commercial fungicides gave fairly good protection when the disease was moderate but failed when infection was severe. Additional fungicides were tested separately against Pythium ultimum and Rhizoctonia solani. Several fungicides were effective against Pythium but best results among seed treatments were obtained with 2 or 4 ounces of 85 percent Bayer 22555 (P-dimethylaminobenzene diazosodium sulfonate) per 100 pounds of seed. Against Rhizoctonia PCNB proved to be the most effective fungicide tested. With soils infested by both Pythium and Rhizoctonia, either PCNB or Bayer 22555, used alone, was ineffective, but when the two fungicides were used together the seedlings were protected. In uniform field trials of seed treatments during 1958, captan, Ceresan 100, Panogen, Bayer 15080, and Bayer 22555 were compared alone and in combination with PCNB. The addition of PCNB to any of the other fungicides significantly improved the protective value of the treatment.

During the past 5 years greenhouse and field trials have been conducted to evaluate the cotton seedling disease problem in California and to identify materials and practices that would be most effective in reducing losses of cotton seedlings from this cause.

Seed treatment of cotton for protection against seed decay and damping-off has been a common practice in California for a number of years. The fungicides in commercial use provide fairly satisfactory protection when seedling diseases are light or moderate but under conditions of severe infestation do not provide the degree of protection desired.

Several years ago it was shown (4) that the addition of an insecticide such as lindane (99.5 percent gamma isomer of benzene hexachloride) to the fungicidal seed treatment would provide protection against wireworms and the seed-corn maggot. Dosage trials in pasteurized soil in greenhouse flats and in enclosed chambers indicated that 75 percent lindane used at the rate of 2 2/3 ounces per 100 pounds of seed was noninjurious to germinating cotton seed but effective as a protectant against wireworms and seed maggots. Under field conditions, however, some observers reported that emergence from cotton seed treated with 2 ounces of lindane per 100 pounds of seed was not as good as from seed treated with lighter dosages of lindane or with the fungicide alone. To measure the value of fungicidal and insecticidal treatments on cotton seed in different cotton-producing areas of California a series of uniform trials was established in 1954 and again in 1955, with the cooperation of farm advisors and experiment station staff. Because seedling insect attacks were almost totally absent from the 20 field trials in 1954 and 1955, no information was collected on the protective value of these insecticides. During 1956, insecticides were tested in a separate program and the fungicide seed treatment trials were expanded to include several additional materials.

In general the results from 28 field trials over a period of 3 years indicated that captan, Ceresan M, or Panogen, the three fungicides in commercial use as cotton seed treatments in California, were about equally effective and that any one of the three provided satisfactory protection with moderate infestations. In a certain number of fields, however, seedling pathogens occurred at a high inoculum level and conditions were favorable for severe seedling infection. Under these conditions none of the seed treatments provided adequate protection.

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[1]Plant Pathologist, University of California, Davis, California.
[2]Plant Pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture.
[3]Entomologist, University of California, Davis, California.

Two fungus organisms, Pythium ultimum and Rhizoctonia solani, are recognized as the main pathogens involved in the cotton seedling disease complex in California and both are known to be present in the soils of most cotton-growing areas. However, these organisms vary in their relative abundance and pathogenic activity according to soil type, climatic conditions, and previous cultural practices.

As new fungicides have become available they have been tested in the laboratory and greenhouse at Davis against each of the seedling pathogens. Some of these fungicides show a high degree of effectiveness against one of these organisms but are so specific in their activity that they are relatively ineffective against the other. By combining certain of these specific fungicides promising results have been obtained where both Rhizoctonia and Pythium were active in the soil.

The relative protective effects of specific fungicides used alone, in combination with each other, or in combination with commercial seed treatment fungicides, were tested in uniform field trials during 1957 and 1958.

PROCEDURE

During each of the 5 years a quantity of clean acid-delinted Acala 4-42 cotton seed secured from the U. S. Cotton Field Station, Shafter, California, was divided by means of a Boerner Sampler into 12 equal lots (8 in 1956 and 1957) which received the treatments indicated. Each treated lot was divided by weight into lots of approximately 200 seeds each. Identical field trials were planted at several locations in typical cotton-producing areas of California under the supervision of the local farm advisors[4]. The treatments were replicated six times in a randomized block design. A single replicate of a treatment consisted of 200 seeds planted in a row approximately 50 feet long. The seed was hand-dropped through the planter tube with the seed hopper removed. Counts were made during emergence and a final count when all post-emergence deaths were thought to have occurred.

EXPERIMENTAL RESULTS

1954 Trials

Complete data concerning emergence and survivors were collected from nine field trials by cooperating farm advisors. To secure a more complete picture of the results throughout the cotton-producing area results of six trials having similar (homogeneous) error mean squares have been pooled according to the method of Roessler and Leach (6). This procedure made possible a more critical evaluation of treatment effects. The pooled data for emergence from six locations and for survivors from five locations are presented in Table 1. For a comparison of lindane and fungicide effects from the pooled data the averages for all plots receiving the same material alone or in combination with others are also presented in Table 1.

These results show that although damping-off was not a serious factor in these trials seed treatment with captan; Ceresan M-2X, or Panogen significantly improved emergence and survival over that from nontreated seed. At the dosage rates used captan did not appear to be quite as effective as the other two fungicides. In subsequent trials the dosage of captan was increased to 2 ounces per 100 pounds of seed.

Lindane alone reduced emergence by a significant amount but when used with a fungicide this adverse effect almost disappeared. When all treatments without lindane are compared with the same treatments with each dosage of lindane the effect on emergence appears to be nonsignificant although the survivor data suggest that the higher dosage is injurious.

The fact that these adverse effects do not occur with the higher rate of lindane in pasteur-

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The field trials were conducted under the supervision of Marvin Hoover, Extension Cotton Specialist, University of California, Shafter, by the following University of California farm advisors: Fresno County, L. K. Stromberg; Imperial County, R. A. Kortsen; Kern County, G. V. Ferry; Kings County, W. L. Hopkins and O. D. McCutcheon; Madera County, C. E. Johnson; Merced County, C. C. Conley; Riverside County, W. M. Lawson; San Bernardino County, R. C. Harkins; Tulare County, A. G. George. The writers would also like to acknowledge the valuable assistance of Dr. Donald C. Erwin, Assistant Plant Pathologist, University of California, Riverside and of Robert C. Lambe, J. C. Harvey and Alex Lange, Senior Laboratory Technicians, University of California, Davis, during portions of these trials.

Table 1. Effect of three fungicides and two dosages of lindane on emergence and survival of cotton -- 1954.

Treatment	Fungicide: Material	Fungicide: Oz/100 lb.	Insecticide: Material	Insecticide: Oz/100 lb.	Emergence[a] percent	Survivors[b] percent
A	None	-	None	--	77.1	66.1
B	None	-	Lindane[f]	1.33	73.2	61.6
C	None	-	Lindane	2.67	73.4	63.1
D	Captan[c]	1	None	--	82.5	70.9
E	Captan	1	Lindane	1.33	82.7	70.2
F	Captan	1	Lindane	2.67	82.4	68.8
G	Ceresan M-2X[d]	1	None	--	84.7	74.1
H	Ceresan M-2X	1	Lindane	1.33	85.2	73.3
I	Ceresan M-2X	1	Lindane	2.67	85.2	71.1
J	Panogen[e]	1.5	None	--	85.2	75.3
K	Panogen	1.5	Lindane	1.33	84.8	72.2
L	Panogen	1.5	Lindane	2.67	85.5	72.5
L.S.D.	19:1				2.54	4.12
	99:1				3.35	5.43
	Effect of Lindane					
	Without Lindane				82.4	71.6
	With 1 1/3 oz. of 75% Lindane				81.5	69.3
	With 2 2/3 oz. of 75% Lindane				81.4	68.8
L.S.D.	19:1				n.s.	2.06
	Effect of fungicides					
	No fungicide				74.5	63.6
	Captan -- 1 oz.				82.5	70.0
	Ceresan M-2X -- 1 oz.				85.0	72.8
	Panogen -- 1.5 oz.				84.8	73.3
L.S.D.	19:1				1.47	2.38
	99:1				2.00	3.00

[a]Average of 6 homogeneous field trials.
[b]Average of 5 homogeneous field trials.
[c]75 percent N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide.
[d]15.4 percent N-(ethylmercuri)-p-toluenesulfonanilide.
[e]2.2 percent cyano (methylmercuri) guanidine.
[f]75 percent lindane (99.5 percent gamma isomer of benzene hexachloride).

ized soil in the greenhouse indicates that injury could be associated with the presence of damping-off organisms in naturally infested soils. Such "predisposing" effects have been observed for certain seeds by Lange and co-workers (5).

1955 Trials

Unlike the 1954 cotton planting season when conditions were quite favorable for germination and emergence, the 1955 season was extremely unfavorable. At the time of the earliest plantings in late March the temperature was favorable for germination; however, soil moisture losses from the surface soil prevented some plantings from completing germination and emergence. Later in the planting season, during much of April and May, rains and cool temperatures slowed germination and severe crusting of the soil reduced emergence thus masking in some cases the possible advantages from seed treatment.

Seed treatment trials were conducted by farm advisors in eight counties. Owing to the

generally unfavorable growing conditions some tests were abandoned. Among the eight trials from which final stand data were obtained only trial 6 (Tulare County) and trial 10 (Madera County) showed a significant improvement in emergence and survival as a result of fungicidal seed treatments. Because of the great variability experienced it was not possible to combine the 1955 trials into a single homogeneous series for purposes of analysis as was done with the 1954 data. The most reliable conclusions can therefore be drawn from an examination of the results from trials 6 and 10, presented in Table 2.

Whereas in the 1954 trials 75 percent captan at 1 ounce per 100 pounds of seed showed less protection than Ceresan M-2X at the same dosage, in the 1955 trials 75 percent captan at 2 ounces per 100 pounds (treatments C and D) gave protection essentially equal to that from Ceresan M-2X (treatments E, F, G, and H).

Mema Special (treatments I and J) appeared to give somewhat less protection than captan or Ceresan in trials 6 and 10. Panogen, which in the 1954 trials appeared to give protection equal to that from Ceresan M-2X, did not provide as good stands in the 1955 trials 6 and 10. It should be pointed out, however, that the combination treatment of Panogen and aldrin did provide protection equal to that from captan or Ceresan M despite the fact that no insect injury was noted in these plantings.

Owing to the low incidence of insects it was impossible in the 1955 trials to compare the value of different insecticides adequately. In trial 10, however, lindane alone improved emergence and survival as compared with nontreated seed, and the Panogen-aldrin combination appeared significantly better than Panogen alone. These results suggest protection against seedling insect attack although the addition of insecticides to captan or Ceresan M-2X did not result in similar increases.

1956 Trials

Because few of the trials in 1954 and 1955 showed enough insect damage to measure the value of insecticidal seed treatments adequately, the 1956 tests were limited to a comparison of fungicides except that one treatment (Ceresan M) was combined with lindane. Separate tests with insecticides in fields known to be infested by seedling insects were conducted by Dr. W. H. Lange.

Whereas the trials in 1954 and 1955 were limited to three and four fungicides, respectively, six fungicides were tested in 1956. The treatments were planted in identical field trials in eight locations ranging from Imperial County in the south to Merced County in central California. Seven of the plantings were carried to completion and the results are presented in Table 3.

Trials 1 and 2, located in Imperial County, showed no improvement in stand as the result of seed treatment. When Erwin and co-workers (3) artificially infested soil in this area with inoculum of both Pythium ultimum and Rhizoctonia solani they observed infection of cotton seedlings by Rhizoctonia but not by Pythium. They therefore concluded that conditions were unsuitable for Pythium ultimum.

Three of the five trials in the San Joaquin Valley showed significant improvement from seed treatment. Because their error variances do not represent a homogeneous series it is not possible to pool the data for a combined analysis and no statistical conclusions can be drawn from comparison of the average stands. In most of the cases, however, the highest emergence was obtained with captan or Ceresan M-2X with only slightly lower stands from Dow 9B, Gallotox, or Panogen.

The addition of lindane to Ceresan M-2X neither increased nor decreased the emergence by a significant amount in any trial and since the average results of these two treatments were nearly identical it can be assumed that insects attacking germinating seedlings were not an important factor in these particular trials. This is in conformity with the observations of the cooperators.

Greenhouse Evaluation of Specific Fungicides

Trials conducted from 1955 through 1957 showed that pentachloronitrobenzene (PCNB) used as a seed treatment gave good protection against Rhizoctonia solani but little or no protection against Pythium ultimum (Tables 4 and 5). Protection of cotton seedlings by PCNB seed treatment has been reported by Arndt (1) and Brinkerhoff (2).

In addition to observations on emergence and survival of seedlings a disease index was calculated for each treatment using the scale 0 = disease-free, 1 = slight hypocotyl infection,

Table 2. Results of cotton seed treatment with fungicides and insecticides -- 1955.

Treatment	Fungicide: Material	Fungicide: Oz. per 100 lb.	Insecticide: Material	Insecticide: Oz. per 100 lb.	Trial number 6: Emergence percent	Trial number 6: Survivors percent	Trial number 10: Emergence percent	Trial number 10: Survivors percent
A	None	--	None	--	60	56	28	26
B	None	--	Lindane[g]	2.67	59	55	43	40
C	Captan[a]	2	None	--	72	67	85	79
D	Captan[b]	2	Lindane	0.63	70	66	82	79
E	Ceresan M-2X[c]	1	None	--	68	65	86	82
F	Ceresan M-2X	1	Lindane	2.67	77	72	82	78
G	Ceresan M-2X	1	Dieldrin[h]	1.33	77	72	87	83
H	Ceresan M-2X	1	Heptachlor[i]	2.00	73	70	87	83
I	Mema Special[d]	4 fl.	None	--	65	62	72	68
J	Mema Special	4 fl.	Lindane	2.67	67	62	69	67
K	Panogen[e]	2 fl.	None	--	67	64	72	67
L	Panogen[f]	2 fl.	Aldrin	3.20	75	71	82	80
Sign Diff. (19:1)					9.9	8.6	8.3	7.8
(99:1)					13.2	11.4	11.0	10.4
Without insecticide					66.6	62.6	68.6	64.4
With insecticide					71.2	66.7	76.0	72.8

[a]Captan -- 75 percent N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide.
[b]Ortho Seed Guard containing 50 percent captan and 16.5 percent lindane.
[c]Ceresan M-2X -- 15.4 percent N-(ethylmercuri)-p-toluenesulfonanilide.
[d]Mema Special -- a mixture of methoxyethylmercury acetate and ethylmercury acetate containing 3.2 ounces of mercury per gallon.
[e]Panogen -- 2.2 percent cyano (methylmercuri) guanidine.
[f]Panogen (PA-2N) containing 0.4 percent cyano (methylmercuri) guanidine and 24.4 percent (aldrin) hexachloro hexahydro-endo-exo-dimethanonaphthalene.
[g]Lindane -- 75 percent (99.5 percent gamma isomer of benzene hexachloride).
[h]Dieldrin -- 75 percent hexachloro-epoxy-octahydro-endo-exo-dimethanonaphthalene.
[i]Heptachlor -- 25 percent heptachloro tetrahydro methanoindene.

Table 3. Effect of seed treatment upon emergence of cotton in seven field trials during 1956.

Treatment	Dosage oz/100 lb.	Percent emergence: Trial no. 1	2	3	4	5	7	8	Average
None	--	52.1	47.8	49.0	60.3	4.3	18.0	31.9	37.6
Captan[a]	2	57.6	51.8	74.2	85.2	39.6	36.2	45.5	55.7
Ceresan M-2X[a]	1	57.9	48.8	69.3	81.8	31.5	27.2	41.4	51.1
Ceresan M-2X + Lindane[a]	1 2/3	53.3	46.0	76.3	88.2	32.1	29.0	34.9	51.4
Dow 9B[b]	2	56.5	47.5	69.1	76.9	20.7	29.1	37.5	48.2
Gallotox[c]	2 fl.	53.2	44.6	67.2	79.7	43.4	20.8	34.2	49.0
Mema[d]	1 1/4 fl.	54.1	45.7	55.6	58.6	5.4	22.2	28.3	38.6
Panogen[a]	2 fl.	57.1	48.1	62.9	78.2	25.4	30.4	30.6	47.5
Sign. Diff. (19:1)		n.s.	n.s.	13.3	8.2	18.1	n.s.	n.s.	
(99:1)		n.s.	n.s.	17.9	11.0	24.2	n.s.	n.s.	

[a]See Table 2.
[b]32 percent zinc 2,4,5-trichlorophenoxide.
[c]7 percent phenylmercury acetate.
[d]11.4 percent 2-methoxyethylmercury acetate.

Table 4. Comparison of Bayer 15080 and PCNB as cotton seed treatments in greenhouse soil pasteurized and then infested by Pythium or Rhizoctonia.

Material	Dosage oz/100 lb.	Pythium Emergence percent	Pythium Survivors percent	Rhizoctonia Emergence percent	Rhizoctonia Survivors percent
Nontreated	--	38	30	7	6
Bayer 15080[a]	2	51	42	60	41
Bayer 15080	4	82	81	60	36
PCNB[b]	4	40	28	83	79
PCNB	8	21	18	90	89
PCNB	12	14	12	83	82
PCNB	16	29	19	83	81
LSD .05		36	34	16	23
LSD .01		ns	ns	23	32

[a]20 percent quinoneoxime benzoyl hydrazone.
[b]75 percent pentachloronitrobenzene.

Table 5. Results of trials with cotton seed treatments in greenhouse soils for protection against Rhizoctonia solani.

Material	Dosage oz/100 lb.	Per 100 seeds Emergence	Per 100 seeds Survivors	Disease index[d]
Nontreated	-	57	40	2.41
Ceresan 100[a]	2	71	26	2.61
Bayer 22555[b]	4	65	42	2.30
PCNB[c]	2	76	65	1.37
PCNB	4	77	71	1.17
PCNB	8	70	67	1.23
LSD .05		ns	20	--
LSD .01		ns	27	--

[a]3.1 percent ethylmercury 2,3-dihydroxypropyl mercaptide and 0.67 percent ethylmercury acetate (2.3 percent Hg).
[b]85 percent P-dimethylaminobenzene diazosodium sulfonate.
[c]See Table 4 (footnote b).
[d]See text for scale.

Table 6. Results of trials with cotton seed treatments in greenhouse soils for protection against Pythium ultimum.

Material	Dosage oz/100 lb.	Trial number 1 Emergence percent	Trial number 1 Survivors percent	Trial number 1 Disease index[d]	Trial number 2 Emergence percent	Trial number 2 Survivors percent	Trial number 2 Disease index[d]
Nontreated	-	13	12	3.6	0	0	4.0
Captan 75[a]	2	--	--	-	63	45	2.6
Ceresan 100[b]	2	34	32	2.9	33	23	3.3
Bayer 15080[c]	2	38	36	2.7	--	--	-
Bayer 15080	4	39	39	2.5	--	--	-
Bayer 22555[b]	1	57	56	1.9	52	38	2.7
Bayer 22555	2	81	80	0.7	66	57	2.0
Bayer 22555	4	94	94	0.3	93	90	0.9
LSD .05		14	15	-	21	23	-
LDS .01		19	20	-	28	31	-

[a]See Table 1. [b]See Table 5. [c]See Table 4. [d]See text.

Table 7. Comparison of effectiveness of Ceresan 100 and Bayer 22555, each at three dosages, in Pythium-infested greenhouse soil.

Material	Dosage oz/100 lb.	Emergence percent	Survivors percent	Disease index[b]
Nontreated	-	31	25	3.4
Ceresan 100[a]	1	40	39	2.9
Ceresan 100	2	55	52	2.4
Ceresan 100	4	70	64	1.9
Bayer 22555[a]	1	84	79	1.5
Bayer 22555	2	90	87	0.8
Bayer 22555	4	86	86	0.7
LSD .05		22	20	-
LSD .01		30	28	-

[a]See Table 5. [b]See text.

2 = moderate to severe hypocotyl infection, 3 = post-emergence damping-off, and 4 = seed decay or pre-emergence damping-off, as determined by examination and comparison with emergence in pasteurized soil.

In our trials, increasing the dosage of PCNB did not result in appreciable improvement of protection against Rhizoctonia. Bayer 15080 (quinoneoxime benzoyl hydrazone) on the other hand gave good protection against Pythium but was relatively ineffective against Rhizoctonia. Captan and Ceresan M or Ceresan 100 usually improved emergence but did not reduce post-emergence infection appreciably (Tables 5, 6, 7).

1957 Trials

During the 1957 planting season captan, ceresan M, and Bayer 15080 were evaluated as seed treatments alone and in combination with PCNB in three field plantings. Although these three trials did not show striking differences between the treatments there were indications that combining PCNB with captan, Ceresan, or Bayer 15080 increased emergence and survival over that obtained from the same fungicides used alone.

In March 1957, another fungicide, Bayer 22555 (P-dimethylaminobenzene diazosodium sulfonate) was offered for testing as a soil fungicide. Greenhouse trials with this material used as a seed treatment on cotton showed that it was extremely effective against Pythium ultimum, especially when the dosage was increased to 2 or 4 ounces per 100 pounds of seed (Tables 6, 7), but was ineffective against Rhizoctonia solani (Table 5). Combination seed treatments with Bayer 22555 and PCNB were outstanding in soils infested with both organisms.

On the basis of these encouraging results uniform trials including several combination seed treatments were conducted in four counties in the San Joaquin Valley of California during 1958. The emergence counts from trials 1 through 5 are presented in Table 8.

Because trial 1 showed a relatively high error variance and trial 3 an exceptionally low error variance it was not possible to combine the five trials for statistical analysis. However, trials 2, 4, and 5 do represent a homogeneous series and were analyzed as a combined group. The average results show that all the fungicides tested, except Bayer 15080 used alone, improved the emergence of cotton seedlings. When PCNB was combined with the other fungicides it produced an additional improvement in each case.

To test the effect of PCNB the average of all plots receiving this fungicide was compared with the average of all plots in the same trial not receiving PCNB. It is clear that PCNB significantly improved emergence in trials 1, 3, and 5 but not in trials 2 or 4. The combined figures for the three homogeneous trials show that without PCNB the average emergence for all treatments was 50 percent while the same treatments with PCNB averaged 60 percent, a highly significant increase.

Among the other fungicides Bayer 15080 appeared to be the least effective while captan, Ceresan 100, Panogen, or Bayer 22555 were all significantly better than no treatment but with little or no differences among them.

Table 8. The effect of seed treatments on emergence of cotton seedlings; results of 1958 seed treatment trials.

Seed treatment[a]	Percent Emergence						
	Trial number					Average of 5 trials	Average of 3 homogeneous trials[b]
	1	2	3	4	5		
None	45	54	79	54	26	52	44
PCNB	63	59	83	51	51	61	54
Captan	61	62	89	63	36	62	53
Captan + PCNB	67	66	89	58	58	68	60
Ceresan 100	75	59	85	65	40	65	54
Ceresan 100 + PCNB	77	61	89	65	62	71	63
Panogen	63	51	84	63	42	61	52
Panogen + PCNB	74	58	88	65	57	68	60
Bayer 15080	57	46	79	57	23	52	42
Bayer 15080 + PCNB	76	57	90	64	59	69	60
Bayer 22555	61	61	84	57	40	61	52
Bayer 22555 + PCNB	70	61	90	63	61	70	63
Sign. Diff. (19:1)	24.4	n.s.	7.0	16.0	13.6	--	9.0
(99:1)	n. s.	n.s.	9.3	n.s.	n.s.	--	11.9
Effect of PCNB							
Without PCNB	60.4	55.6	83.1	59.8	34.6	58.83	49.7
With PCNB	71.0	61.0	88.2	60.8	58.1	67.83	59.9
Sign. Diff. (19:1)	10.0	7.4	2.9	n.s.	5.5	--	3.7
(99:1)	n.s.	n.s.	3.8	n.s.	7.3	--	4.9
Effect of other fungicides							
None	53.9	56.8	80.9	52.4	38.6	56.5	48.8
Captan	64.1	63.9	88.7	60.4	47.1	65.0	56.7
Ceresan 100	76.2	59.9	86.9	64.5	51.4	68.0	58.5
Panogen	68.3	54.4	85.9	63.8	49.3	64.5	55.9
Bayer 15080	66.5	51.7	84.7	60.5	41.1	60.5	51.1
Bayer 22555	65.2	63.5	86.8	60.2	50.5	65.5	57.8
Sign. Diff. (19:1)	17.3	n.s.	5.0	11.3	9.5	--	6.4
(99:1)	n.s.	n.s.	6.6	n.s.	n.s.	--	8.4
C of V	32.2	29.6	6.8	23.0	25.4		24.3

[a]Pentachloronitrobenzene (75 percent PCNB) was applied at 4 ounces per 100 pounds of seed; all other fungicides were applied at 2 ounces per 100 pounds of seed. For composition of the formulated fungicides see footnotes Tables 1, 4, and 5.

[b]Average of trials 2, 4, and 5 were combined on the basis of similar error variances.

SUMMARY AND DISCUSSION

Most of the fields used for cotton planting in the San Joaquin Valley of California are infested with eigher Pythium ultimum or Rhizoctonia solani and usually both organisms are present but at varying inoculum levels. The seed treatments currently used in commercial practice provide considerable protection but are considered inadequate under conditions of severe infestation. This has stimulated interest in localized placement of fungicides in the seed furrow and in the development of more effective seed treatments.

In most instances insecticides combined with fungicides did not result in improved stands owing to the low incidence of insect attack, but in one case an increase in emergence was obtained with a Panogen-aldrin combination. Lindane used in the absence of a fungicide in certain tests resulted in a slight stand decrease.

In greenhouse experiments and in limited field trials it has been found that seed treatment with pentachloronitrobenzene (PCNB) provided improved control of Rhizoctonia infection and that its addition to the seed treatments now in commercial use improved emergence and survival of cotton seedlings in soils infested by both Pythium and Rhizoctonia.

Similar trials in soils infested by Pythium ultimum showed that an experimental fungicide, Bayer 22555, used as a seed treatment was extremely effective in protecting cotton seedlings against this organism.

The specificity of these two fungicides is indicated by the fact that PCNB offered little or no protection against Pythium whereas Bayer 22555 was ineffective against Rhizoctonia. It followed that neither material used alone offered protection in soils with mixed infestation.

When PCNB was combined with Bayer 22555, each at its optimum dosage, a higher level of protection was observed in soils infested with both Pythium and Rhizoctonia than with other fungicides tested.

In field trials with moderate infestations the PCNB-Bayer 22555 was equal to but no better than PCNB combined with captan, Ceresan 100, or Panogen. These results suggest the possibility of using suitable combinations of specific fungicides to secure higher levels of protection than is usually obtained from our present commercial seed treatments.

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DEPARTMENT OF PLANT PATHOLOGY, UNIVERSITY OF CALIFORNIA, DAVIS, CALIFORNIA

DISEASE SUSCEPTIBILITY OF COTTON SEEDLINGS FROM ARTIFICIALLY DETERIORATED SEEDS[1]

Katharina Bollenbacher and N. D. Fulton[2]

Abstract

Pathogenicity tests were carried out at 21° and 27° C with cotton seeds which had been deteriorated to different degrees by heating at 50° in a moist atmosphere for various periods. Although emergence of deteriorated seeds was reduced in proportion to the degree of deterioration even in the absence of fungus inoculum, such fungi as Alternaria sp., Aspergillus flavus Link, Aspergillus niger van Tieghem, Colletotrichum gossypii South., Fusarium moniliforme Sheld., F. oxysporum Schlecht., F. oxysporum f. vasinfectum (Atk.) Snyder & Hansen, Helminthosporium sp., Rhizopus sp., Sclerotium bataticola Taub., Thielaviopsis basicola (Berk. & Br.) Ferr., and Trichoderma sp. caused additional suppression in emergence of deteriorated seeds. The degree of susceptibility of the seeds to injury by these fungi usually increased as the deterioration period was lengthened. Most of the microorganisms caused a greater reduction in emergence of deteriorated seeds at 21° than at 27° C. Pythium ultimum Trow and a virulent isolate of Rhizoctonia solani Kuehn completely inhibited emergence of all seeds, including undeteriorated ones. Increased susceptibility to fungus attack as a result of seed deterioration was observed less frequently in the post-emergence stage of seedling growth than in the pre-emergence phase. However, test results with some of the moderately pathogenic microorganisms indicated that these fungi were more damaging to emerged plants from deteriorated seeds than to those from good-quality seeds. Very few seedlings survived in the tests with C. gossypii or with T. basicola regardless of whether or not the seeds had been deteriorated. Isolates of Cladosporium sp., Penicillium sp., and Verticillium albo-atrum Reinke & Berth. caused little or no damage to any seeds or seedlings.

INTRODUCTION

Previous investigators have shown that damage to seeds caused by unfavorable field or storage conditions may result in reduced viability (8, 9, 10) and in the production of plants of reduced size and low vigor (11). It has been assumed that such plants are predisposed to disease, although there appears to be little experimental evidence to support such an assumption. In the past it was difficult to obtain information on this subject because no quick laboratory method which would duplicate natural deterioration was available. Presley (5, 6) recently devised a rapid method for artificially deteriorating cotton seeds to various degrees in the laboratory. It was decided that tests with such artificially deteriorated seeds would be useful as a guide in determining whether or not cotton seedlings from naturally deteriorated seeds are predisposed to disease. Consequently, an experiment was set up in which cotton seeds deteriorated to various degrees by Presley's method were tested against a number of fungi isolated from diseased cotton seedlings. Included in the series were fungi known to be pathogenic to cotton seedlings and also several fungi commonly considered relatively nonpathogenic despite the fact that they are recovered from almost all field collections of diseased cotton seedlings (2, 3, 4, 7, 12).

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[2] Plant Pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, and Associate Plant Pathologist, Arkansas Agricultural Experiment Station, respectively.

METHODS AND MATERIALS

A single lot of Hale 33 cotton seed, 1956 crop, was used for the entire series of tests. The seeds were acid-delinted and gravity-graded. All cracked and otherwise obviously damaged seeds were discarded. The seeds were allowed to dry at room temperature and then aliquots were held at 50° C and 100 percent relative humidity for 24, 48, 72, and 96 hours. Presley (5) demonstrated that the length of time the seeds could be subjected to these conditions before becoming deteriorated was greatly influenced by their moisture content. Therefore, the moisture contents of the seeds, both initially and at the end of each 24-hour period of conditioning, were determined by calculating the loss in weight of the seeds after drying at 100° C for 24 hours. The initial moisture content of the seed lot used in the present tests varied from 7 to 10 percent during the course of the work. After conditioning, the average moisture contents of the seeds were as follows: 24 hours, 10 percent; 48 hours, 12 percent; 72 hours, 13 percent; 96 hours, 14 percent. The percentage germination of the seeds was determined by placing samples of each aliquot between moist filter paper in Petri dishes and incubating them at constant temperatures of 16°, 20°, and 28°.

Pathogenicity tests with the conditioned seeds were carried out in sand cultures in the greenhouse at constant temperatures of 21° and 27° C. The fungus inoculum for the tests was produced in a liquid medium consisting of a modified Richard's solution in which dextrose was substituted for sucrose and V-8 juice was added. When the fungus cultures were ready for use the medium was decanted and replaced with an equal volume of distilled water. The fungus growth was comminuted in the Waring Blendor and a standard volume of the suspension was thoroughly mixed with sterilized sand in 1-gallon crocks. In all tests 20 seeds were planted in each crock of sand at a uniform depth of 1/2 inch immediately after conditioning. A standard volume of distilled water was added to each crock daily. Beginning shortly after emergence the plants were given a balanced nutrient solution each day. Uninoculated control crocks containing the complete series of conditioned and unconditioned seeds were included in each test. Each experiment contained three replicates of each microorganism and of the uninoculated controls with each type of seed. Emergence counts were taken 12 days after planting. Three weeks after planting the seedlings were pulled up and rated for post-emergence disease. For the uninoculated checks the emergence data were calculated as percent of the total number of seeds planted. For the inoculated series emergence data were computed as percentages of plants emerging in each inoculated unit compared with the emergence in the uninoculated check with the same degree of seed deterioration. Post-emergence disease was rated by means of an index calculated by multiplying the number of plants with slight disease symptoms by 20, moderately injured plants by 40, severely injured plants by 60, and dead plants by 100, and dividing the sum by the total number of plants emerged in the particular treatment being rated. Therefore, the indices give disease ratings only for the seedlings which actually emerged and ignore pre-emergence damping-off and seed decay.

RESULTS

In the uninoculated controls the conditioned seeds showed an inverse correlation between emergence and degree of deterioration. The longer the period of deterioration the fewer the plants that emerged. This was evident at both temperatures, although the emergence percentages were slightly higher at 27° C (Table 1). In the controls there was also a progressive reduction in size of the seedlings proportionate to the length of time the seeds had been deteriorated. The emergence data indicate that deterioration of the seeds usually did not begin until they had been conditioned about 48 hours. The number of plants emerging from the 24-hour seeds was approximately the same as from unconditioned seeds and in the 48-hour seeds emergence was only slightly reduced. In all the experiments there was a considerable decrease in emergence of plants from seeds conditioned 72 hours. With 96-hour seeds the emergence in sterile sand was drastically reduced (Table 1). The results of the laboratory germination tests with the conditioned seeds were in agreement with the data for emergence of seedlings in sterile sand except that the laboratory germination percentages were usually slightly higher.

The results of the pathogenicity tests with the various fungi indicate that they fall into two groups: 1) those which caused injury only in the pre-emergence phase of seedling development, and 2) those which caused injury in both the pre-emergence and post-emergence phases. The damage caused by the first group of fungi is measured by any reduction in emergence of the seedlings in addition to that which occurs in the deteriorated seeds even in the absence of fungus growth. The emergence data obtained with these fungi are recorded in Table 1. When the seeds were tested against Pythium ultimum and against Rhizoctonia solani 118-O no plants emerged

Table 1. Seedling emergence from artificially deteriorated cotton seeds inoculated with fungi pathogenic only in the pre-emergence phase at 21° and 27° C.

Fungus and isolate number	Percentage emergence at designated temperatures (°C) from seeds artificially deteriorated for :[a]									
	0 hours		24 hours		48 hours		72 hours		96 hours	
	21°	27°	21°	27°	21°	27	21°	27°	21°	27°
Check	93	94	95	93	80	83	51	69	18	31
Pythium ultimum (1501-O)	0	0	0	0	0	0	0	0	0	0
Rhizoctonia solani (118-O)	0	0	0	0	0	0	0	0	0	0
Rhizopus sp. (1002-F)	76	74	69	83	51	70	40	52	38	18
Trichoderma sp. (1202-F)	79	98	77	100	73	93	59	53	12	100
Alternaria sp. (304-WR)	95	100	90	100	83	100	76	89	10	100
Helminthosporium sp. (803-N)	93	89	93	100	97	100	99	100	44	100

a Emergence counts were taken 12 days after planting. Check emergence is the percentage of seedlings emerging compared with the number of seeds planted. The emergence of each inoculated series is the percentage of seedlings emerging compared with the emergence in its respective check.

Table 2. Seedling emergence from artificially deteriorated cotton seeds inoculated with fungi pathogenic both in the pre-emergence and post-emergence phases at 21° and 27° C.

Fungus and isolate number	Percentage emergence at designated temperatures (°C) from seeds artificially deteriorated for :[a]									
	0 hours		24 hours		48 hours		72 hours		96 hours	
	21°	27°	21°	27°	21°	27°	21°	27°	21°	27°
Check	93	94	95	93	80	83	51	69	18	31
Colletotrichum gossypii (611-O)	49	89	58	87	47	67	20	40	12	17
Thielaviopsis basicola (1313-O)	76	96	67	99	50	89	25	81	0	50
Rhizoctonia solani (1123-F)	7	58	0	45	0	37	0	27	0	0
Aspergillus flavus (411-O)	100	94	88	100	92	93	68	82	51	75
A. niger (422-G)	96	87	94	97	82	99	72	64	100	34
Fusarium oxysporum (2028-G)	100	98	97	95	78	97	69	93	14	72
F. oxysporum f. vasinfectum (2018-F)	96	95	83	100	80	96	71	35	0	0
F. moniliforme (217-F)	82	99	82	100	69	97	88	92	0	50
Sclerotium bataticola (1114-M)	97	96	95	91	86	90	81	68	71	50

a Emergence counts were taken 12 days after planting. Check emergence is the percentage of seedlings emerging compared with the number of seeds planted. The emergence of each inoculated series is the percentage of seedlings emerging compared with the emergence in its respective check.

Table 3. Pathogenicity of various fungi to emerged seedlings from artificially deteriorated cotton seeds at 21° and 27° C.

Fungus and isolate number	Post-emergence disease at designated temperatures (°C)[a] Seeds artificially deteriorated for:									
	0 hours		24 hours		48 hours		72 hours		96 hours	
	21°	27°	21°	27°	21°	27°	21°	27°	21°	27°
Check	0	0	0	0	0	0	0	0	0	0
Colletotrichum gossypii (611-O)	100	100	100	100	100	100	100	100	100	100
Thielaviopsis basicola (1313-O)	100	68	100	69	100	64	100	70	--[b]	82
Rhizoctonia solani (1123-F)	13	40	--	45	--	49	--	33	--	--
Aspergillus flavus (411-O)	30	26	32	30	40	32	32	35	29	44
A. niger (422-G)	22	6	21	8	27	9	22	16	22	14
Fusarium oxysporum (2028-G)	13	18	14	22	16	22	24	31	19	36
F. oxysporum f. vasinfectum (2018-F)	17	2	23	5	12	9	23	54	--	--
F. moniliforme (217-F)	0	9	0	12	0	16	19	21	--	38
Sclerotium bataticola (1114-M)	16	13	17	15	17	17	18	31	38	29

a Post-emergence disease index: slight injury 20; moderate injury 40; severe injury 60; death 100.
b No emergence.

regardless of whether they had been deteriorated or not. Rhizopus sp. caused some reduction in emergence with all types of seeds at both temperatures but the reduction was greater in the deteriorated ones. The longer the seeds were subjected to the deterioration process the more susceptible they were to attack by Rhizopus sp. The effect of Trichoderma sp. on emergence was similar to that of Rhizopus sp. at 21° C, but the former was much less destructive than the latter at 27°. Alternaria sp. and Helminthosporium sp. both depressed emergence of seeds with prolonged deterioration in the 21° C tests, but had little or no effect on seedling emergence at 27°.

Emergence data obtained with fungi belonging to the second group are recorded in Table 2. Colletotrichum gossypii and Thielaviopsis basicola both caused severe post-emergence disease in the seedlings, but with seeds of high vigor they did not appreciably depress emergence at 27° C. However, in deteriorated seeds these two fungi caused a drastic reduction in emergence, particularly if the deterioration was prolonged. R. solani 1123-F, a less virulent strain of this fungus than the isolate described previously, permitted considerable emergence of seedlings at 27° but almost none at 21°. In the 27° test with this fungus seedling emergence was depressed in proportion to the degree of seed deterioration. Aspergillus flavus and A. niger both caused reduction in emergence of deteriorated seeds and the degree of suppression usually increased with the length of time the seeds had been deteriorated. Fusarium oxysporum depressed emergence of deteriorated seeds to a greater extent at 21° than at 27°. F. oxysporum f. vasinfectum and F. moniliforme both caused reduction in emergence of deteriorated seeds at each test temperature. Deteriorated seeds were likewise more susceptible than undeteriorated seeds to attack by Sclerotium bataticola, as is shown by the reduction in emergence of 72- and 96-hour seeds.

Table 3 gives post-emergence disease indices for fungi which damaged the emerged seedlings. C. gossypii, one of the most virulent cotton seedling pathogens (1, 2), killed all plants regardless of whether the seeds had been deteriorated. T. basicola was almost as severe in its attack, but some plants did survive in the 27° C experiment. In this test disease indices for plants from the 72- and 96-hour deteriorated seeds were only slightly higher than those for plants from undeteriorated seeds. In the 27° test with R. solani 1123-F the number of surviving plants

and the severity of disease symptoms did not appear to be related to the degree of seed deterioration. Cotton seedlings grown in sand inoculated with A. flavus usually are stunted, have very short, stubby tap roots and few or no secondary roots (2). In these studies with deteriorated seeds nearly all seedlings infected with A. flavus showed these symptoms to some degree. However, in the test carried out at 27° it was apparent that plants from the 0- and 24-hour conditioned seeds were not so severely affected by the fungus as those from deteriorated seeds. The differences were not great, but seedlings from the 72- and 96-hour seeds were more stunted and had fewer secondary roots than the 0- and 24-hour plants. Many of the plants grown in the presence of A. niger were stunted and had discolored, poorly developed root systems. These symptoms were rather mild, as shown by the disease indices in Table 3. Seedlings from deteriorated seeds were often more severely affected by A. niger than plants from undeteriorated seeds, but the results were not entirely consistent. Fusarium spp. often caused more disease in seedlings from deteriorated seeds than in those from undeteriorated seeds, but usually the symptoms were not severe. On many plants S. bataticola produced dark-brown lesions at the soil line and occasionally the lesions penetrated deeply enough to cause death of the seedlings. Injury was more severe at 72- and 96-hour deterioration than at 0, 24, or 48 hours, but the increase in severity of symptoms with increasing degree of seed deterioration was not very great.

Cladosporium sp., Penicillium sp., and Verticillium albo-atrum caused little or no pre- or post-emergence disease in seedlings from either deteriorated or undeteriorated seeds.

DISCUSSION AND CONCLUSIONS

The purpose of the experiments just described was to determine whether deteriorated cotton seeds and the seedlings they produce are more susceptible to disease than undeteriorated seeds and the seedlings resulting from them. The data provide substantial evidence that the deteriorated seeds were vulnerable to seed decay and pre-emergence damping-off than were undeteriorated ones and that the longer the seeds were subjected to the deterioration process the greater was the degree of susceptibility. Most of the so-called nonpathogenic fungi caused sizable reductions in emergence of deteriorated seeds without appreciably affecting undeteriorated ones. These reductions in emergence of deteriorated seeds in the inoculated series represent a suppression in addition to that which occurred even in the absence of disease organisms. The data for Colletotrichum gossypii and Thielaviopsis basicola indicate that these fungi depress the emergence of deteriorated seeds more than that of good-quality seeds. However, other highly pathogenic fungi, such as Pythium ultimum and Rhizoctonia solani, were very destructive even to carefully selected, undeteriorated seeds. With the majority of the fungi the reduction in emergence with deteriorated seeds was greater at 21° than at 27° C, which is in agreement with Presley's report (5) that unfavorable temperatures place deteriorated seeds at an even greater disadvantage in comparison with those of good quality.

The fungi which were more pathogenic to seedlings from deteriorated seeds than to those from undeteriorated seeds did their principal damage to the plants in the pre-emergence stage. However, in tests with some of the moderately pathogenic fungi plants from deteriorated seeds had slightly higher post-emergence disease indices than those from good-quality seeds. With the methods used in this study it is difficult to determine whether emerged seedlings from deteriorated seeds are predisposed to attack by the extremely virulent pathogens since these fungi killed nearly all plants regardless of the degree of seed deterioration.

Fulton and Bollenbacher (2) found in pathogenicity tests with cotton seedlings involving both pathogenic and nonpathogenic fungi that a slight depression in emergence was produced even by fungi which otherwise caused no disease symptoms in the seedlings. The seed lots used in those tests were not selected and probably contained some naturally deteriorated seeds. The reduction in emergence with fungi which are not otherwise pathogenic may have been due solely to their action on naturally deteriorated seeds in unselected seed lots.

The experimental results reported here also suggest a partial explanation for the increased stands derived from cotton seeds treated with fungicides. The seed treatment may increase emergence by giving naturally deteriorated seeds some degree of protection against emergence-depressing fungi.

The findings reported emphasize the importance of using good-quality cotton seeds for planting, particularly if unfavorable growing conditions are likely to occur.

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DEPARTMENT OF PLANT PATHOLOGY, UNIVERSITY OF ARKANSAS, FAYETTEVILLE, ARKANSAS

RESPONSE OF COTTON VARIETIES TO SEED DETERIORATION AND THE INFLUENCE OF SEED TREATMENT ON DETERIORATION

L. S. Bird and Cyril W. Blackmon[1]

Abstract

Presley's method of artificially deteriorating cottonseed was used to compare 12 varieties and for comparing the influence of seed protectant fungicides on deterioration. Of the varieties studied, seed of Acala 1517c deteriorated faster than the other varieties while seed of Floyd 8G, Delfos 9169 and Northern Star No. 11 had the slowest rate of deterioration. The results suggested that progress in selecting for resistance to seed deterioration could be made.

The seed treatment results indicated that seed treated with protectant fungicides, especially at the higher rates, tend to deteriorate faster than untreated seed.

Recent research has emphasized that the failure to obtain a good stand of cotton due to seedling disease is closely associated with the condition of planting seed (2, 3, 4). Seedlings from poor seed, that is, deteriorated seed or seed exposed to excessive moisture while in the field or in storage, are slow in emerging and they are more apt to be attacked by seedling disease fungi (2, 3). Seedlings from deteriorated seed also are susceptible to a wider range of soil-borne fungi (1, 3). A laboratory method (3, 4) for deteriorating seed has been developed. Complete deterioration is obtained in about 6 days. The actual time depends on the initial moisture content and previous amount of deterioration of the seed. Thus, the method is readily adaptable to studies of all phases of seed deterioration and how it influences seedling disease.

MATERIALS AND METHODS

Seeds of the 12 standard varieties of the Texas Statewide cotton variety testing program were used for variety comparison. The seeds[2] were from the 1957 A. and M. College Plantation irrigated variety test. The seedcotton for all varieties was stored together and all were ginned the same day on a saw gin. The seeds were acid-delinted before initiating the experiment.

Seeds of the Deltapine 15 variety were used for the seed treatment test. Seedcotton from 1-day-open bolls was harvested and ginned on a roller gin. The seeds were acid-delinted and the floaters were discarded. The delinted seeds were treated with the seed protectant fungicides before initiating deterioration.

The seed deterioration method given by Presley (4) was used for the experiments. Half-pint laboratory jars were used to hold 50-gram seed lots and a container with 50 cc of water. Small narrow neck cream jars were used for the water containers. Filter paper wicks were inserted into each water jar to insure free evaporation. The half-pint jars containing the seeds and water jars were sealed and placed in a constant-temperature oven at 50° C. Samples were taken daily for determining seed moisture and seed germination. The seeds were placed in moisture chambers in a 76° F constant-temperature room for determining the amount of germination. Counts were made the second, fourth and fifth days after beginning the germination tests. Values for the second and fourth days indicate the germination rate while the fifth day counts indicate the maximum germination. The average of the 3 day counts was used to repre-

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[1] Assistant Professor, Texas Agricultural Experiment Station and Agent, Crops Research Division, Agricultural Research Service, United States Department of Agriculture; and Plant Pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Department of Plant Physiology and Pathology, College Station, Texas, respectively.

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Table 1. Cotton varietal differences in seed deterioration.

Varieties	Germination for days of seed deterioration[a]				
	2	4	5	6	7
Floyd 8G	24.0	18.4	19.2	2.9	2.4
Delfos 9169	24.0	17.5	18.0	1.8	1.8
Northern Star #11	23.0	21.3	18.9	2.3	1.5
Stoneville 7	24.2	16.4	10.1	0.5	0.5
Malones Rowden	22.9	20.8	10.4	2.3	0.4
Empire WR	23.6	22.3	11.1	5.4	0.0
Lankart Sel. 57-5	22.2	20.1	12.1	3.9	0.0
Deltapine TPSA	24.7	20.6	12.0	3.4	0.0
Brazos	23.5	15.9	14.3	0.3	0.0
Deltapine 15	22.6	18.4	12.2	0.0	0.0
Deltapine Fox	24.7	20.8	11.3	0.0	0.0
Acala 1517c	23.9	13.9	8.7	0.0	0.0
L.S.D. .01	n.s.d.	6.6	5.1	5.3	2.2
L.S.D. .05		4.9	3.8	4.0	1.7

[a] An average of 25 equals 100% germination.

Table 2. Cotton varietal differences in germination rate of seed deteriorated five and six days.

Varieties	Germination for days of seed deterioration and germination[a]					
	5			6		
	2	4	5	2	4	5
Floyd 8G	12.5	22.5	22.5	0.3	3.8	4.5
Delfos 9169	14.3	19.8	19.8	0.0	2.7	2.8
Northern Star #11	11.5	22.2	23.0	0.2	2.8	3.8
Stoneville 7	4.3	12.8	13.2	0.0	6.7	8.3
Malones Rowden	8.0	11.0	12.0	0.0	3.5	3.5
Empire WR	6.8	13.2	13.3	1.7	7.3	7.3
Lankart Sel. 57-5	5.8	15.2	15.3	0.2	5.8	5.8
Deltapine TPSA	9.7	13.0	13.3	1.0	4.8	5.5
Brazos	11.2	15.5	16.2	0.0	0.3	0.7
Deltapine 15	3.0	16.5	17.0	0.0	0.0	0.0
Deltapine Fox	10.5	11.8	11.8	0.0	0.0	0.0
Acala 1517c	1.0	12.3	12.7	0.0	0.0	0.0
Average	8.2	15.5	15.8	0.3	2.7	2.9

[a] An average of 25 equals 100% germination.

sent the germination value for varieties. Therefore, the size of the value reflects both germination rate and total germination.

Three replications were used for the variety comparison test and two were used for the seed treatment test.

RESULTS

Seed germination data for the 12 varieties after 2, 4, 5, 6, and 7 days' deterioration are given in Table 1. In general, germination decreased with length of deterioration. There were no significant differences in germination among the varieties after 2 or 3 (not given in Table 1) days' deterioration. Acala 1517c showed significant deterioration as reflected in decreased germination after 4 days. Floyd 8G, Delfos 9169, and Northern Star No. 11 deteriorated less than the other varieties, as shown by better germination after 5 days. There were no real differences among varieties after 6 days, although Deltapine 15, Deltapine Fox, and Acala 1517c had ceased to germinate by then, nor after 7 days, when only Floyd 8G, Delfos 9169, Northern Star No. 11, Stoneville 7, and Malones Rowden still maintained some ability to germinate.

The second, fourth and fifth days' germination counts for the fifth and sixth days of deterioration are given in Table 2. Floyd 8G, Delfos 9169, Northern Star No. 11, Brazos, and Deltapine Fox tended to have faster germination rates after 5 days' deterioration. Empire WR and Deltapine TPSA tended to have higher germination rates after 6 days.

From the standpoint of selecting for resistance to seed deterioration, selections for some varieties would have to be made the second day of germination after 6 days' deterioration, while for other varieties selections would have to be made the fourth day of germination. Selections for some varieties would have to be made after 5 days' deterioration.

Percent seed moisture data for the varieties by days of deterioration are given in Table 3. The biggest change in moisture occurred from the first to the second day and from the sixth to the seventh day. Seeds of some varieties gained moisture from the fifth to the sixth day while those of others lost moisture. The deterioration rank number for the varieties in Table 1 is given in Table 3 along with the moisture change from the fifth to the sixth day. Positive changes in moisture content tended to be higher for the more slowly deteriorating varieties and lower for the more rapidly deteriorating ones. The higher negative moisture changes were associated with varieties which were intermediate in deterioration rank.

The results of the seed treatment-seed deterioration experiment for days of deterioration are given in Table 4. Seed treated with 2 ounces of Ceresan 100 did not deteriorate more rapidly than the control. Germination at the 3-ounce rate was higher than in the control after 1 and 4 days, but dropped after the fifth day. Seed treated with 3 ounces of Dow 9B showed reduced germination after 5 days' deterioration. Germination at the 4-ounce rate was lower after 4 days' deterioration, and after 5 days was significantly lower, than in the control. Seed treated with Captan 75 gave germination values similar to those for Dow 9B.

The rate of germination for the treated seed after 5 days' deterioration is given in Table 5. Germination was reduced at the higher treatment rates. Ceresan 100 used at 2 ounces was the only treatment that tended to increase the germination rate. The influence of deterioration on the germination rate is better shown with the seed treatment data in Table 6. The germination rate was reduced slightly from zero day to the first day. There was no change from the first through the fourth day of deterioration. The big reduction was from the fourth to the fifth day.

The moisture content of the treated seeds by days of deterioration is given in Table 7. Beginning on the fourth day the treated seeds tended to have a higher moisture content than the control. This trend continued through the fifth day. On the sixth day only seeds treated at the 2-ounce rate of Ceresan 100, the 3-ounce rate of Dow 9B, and both rates of Captan 75, had higher moisture contents than the controls.

DISCUSSION

These seed deterioration results, although preliminary, emphasize the importance of the artificial deterioration method as a tool in seedling disease investigations. The indications of varietal differences in seed deterioration rates suggest that this character may be heritable. If this should prove to be so, progress in selecting for resistance to seed deterioration could be made. With this type of resistance added to commercial varieties the problem of producing high quality planting seed would be reduced. Seedlings of such varieties would be less apt to be damaged or killed by seedling disease fungi.

Table 3. Percent moisture by days of deterioration for cottonseed of twelve varieties.

Varieties	Percent seed moisture for days of deterioration					Deterioration rank	Moisture change from 5th to 6th day
	1	2	5	6	7		
Northern Star #11	8.0	10.9	14.3	16.9	15.6	3	+2.6
Floyd 8G	7.9	10.9	14.9	16.4	15.7	1	+1.5
Brazos	8.3	12.6	14.8	15.7	17.1	9	+0.9
Delfos 9169	8.6	11.6	14.9	15.6	17.2	2	+0.7
Deltapine Fox	8.8	11.4	15.4	15.9	18.2	11	+0.5
Deltapine 15	9.0	11.3	15.6	15.9	16.8	10	+0.3
Stoneville 7	8.6	11.2	15.9	16.1	16.8	4	+0.2
Deltapine TPSA	8.1	10.3	16.0	15.5	17.9	8	-0.5
Malones Rowden	8.1	10.0	15.6	15.0	17.5	5	-0.6
Lankart Sel. 57-5	9.1	11.2	16.0	15.4	19.1	7	-0.6
Acala 1517c	9.0	11.4	15.7	14.9	16.2	12	-0.8
Empire WR	9.0	11.2	16.0	15.0	18.5	6	-1.0

Table 4. The influence of seed treatment on seed deterioration.

Days of deterioration	Average germination[a]							Average[b] for days
	Control	Ceresan 100		Dow 9B		Captan 75		
		2 ozs.	3 ozs.	3 ozs.	4 ozs.	2 ozs.	4 ozs.	
0	24.7	25.0	23.0	24.0	23.8	24.7	24.3	24.2
1	20.7	23.8	24.3	18.8	20.5	24.8	18.7	21.7
4	21.8	21.5	24.0	23.3	16.0	19.2	18.7	20.6
5[c]	17.0	18.8	14.5	12.5	7.5	11.3	4.0	12.2
6	1.3	0.0	1.3	0.0	0.0	0.0	0.0	0.3

[a] An average of 25 equals 100% germination.

[b] The first and 4th days are significantly lower than 0 day, the 5th day is significantly lower than the 1st and 4th days and the 6th day is significantly lower than the 5th day.

[c] L.S.D. for treatments for the 5th day, 1% level 9.3, 5% level 6.1.

Table 5. The influence of seed treatment on the fifth day of seed deterioration.

Days of Germination	Average germination[a]							Average
	Control	Ceresan 100		Dow 9B		Captan 75		
		2 ozs.	3 ozs.	3 ozs.	4 ozs.	2 ozs.	4 ozs.	
2	6.0	8.5	6.5	3.5	2.5	4.0	0.0	4.4
4	22.5	24.0	18.5	17.0	10.0	15.0	6.0	16.1
5	22.5	24.0	18.5	17.0	10.0	15.0	6.0	16.1

[a] An average of 25 equals 100% germination.

The results point out that the deterioration time for effective selection would vary with different varieties. The specific number of days of deterioration and days of germination used for selection would have to be established for the particular variety under consideration.

The results also indicate that seeds of Acala 1517c deteriorate faster than seeds of the other varieties studied. This variety was developed in the Southwestern area, and probably has undergone less natural selection for resistance to seed deterioration than the other varieties. This circumstance further suggests that progress in selection could be made.

The fact that Acala 1517c possesses the highest degree of seedling vigor among the varieties studied suggests that seedling vigor and resistance to seed deterioration may be negatively associated. For this reason selections for resistance to seed deterioration should be evaluated for seedling vigor also.

Table 6. The influence of seed deterioration on the germination rate.

Days of Germination		Germination for days of deterioration[a]				
		0	1	4	5	6
2		22.6	15.5	15.6	4.4	0.0
4		25.0	24.7	23.1	16.1	0.6
5		25.0	24.7	23.1	16.1	0.6
L.S.D.	.01	n.s.d.	9.5	8.2	11.0	n.s.d.
	.05		4.1	3.6	4.8	

[a] An average of 25 equals 100% germination.

Table 7. Percent moisture by days of deterioration for cottonseed treated with protectant fungicides.

Treatments		Percent seed moisture for days of deterioration				
		0	1	4	5	6
Control		7.7	9.7	11.7	12.9	13.6
Ceresan 100	2 ozs.	7.9	9.5	13.3	13.5	14.1
	3 ozs.	7.9	8.9	12.5	12.9	13.9
Dow 9B	3 ozs.	7.5	9.0	13.7	15.6	15.7
	4 ozs.	7.6	10.6	13.5	14.2	13.6
Captan 75	2 ozs.	7.5	10.4	12.8	14.5	14.7
	4 ozs.	7.8	9.3	14.1	15.4	16.3

Results with seed treated with protectant fungicides indicate that possibly the factor of seed deterioration should be considered in evaluating seed protectants as well. The results indicate that high quality seed treated with certain fungicides would deteriorate faster after planting, especially if conditions unfavorable for germination, such as cool, wet soil, last for several days. The fungicide, although protecting the seed from soil-borne fungi, could cause the seed to become less viable sooner than it normally would. Moreover, the results indicate that perhaps seed treated with certain materials deteriorates faster in storage than untreated seed, especially if conditions are unfavorable.

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A LINT-ROT OF COTTON IN CALIFORNIA CAUSED BY NIGROSPORA ORYZAE[1]

Byron R. Houston and Richard H. Garber[2]

Summary

During the past several years Nigrospora has been found responsible for a cotton lint-rot ranging in severity from a trace to as high as 15 percent of the bolls affected on individual plants. The rot has been most important in the central-east side of the San Joaquin Valley cotton-growing area. Infection occurs at or just before initiation of boll opening and results in a gray rot of the lint and a failure to fluff. The affected lock often falls from the bolls before picking unless it is only partially invaded by the fungus. Typical rot has been induced by inoculations in the field and the greenhouse.

INTRODUCTION

The fungus Nigrospora oryzae (Berk. & Br.) Petch (Basisporium gallarum Moll.) has been reported as the causal agent of diseases of a number of monocotyledonous species (2, 3, 7, 8, 9, 11). The most commonly reported host was maize on which the fungus was active as an ear and stalk rot. Nigrospora has also been reported as being associated with a rot of potato tuber (4), tomato fruit (10), and apple fruit (1). In 1929, Jaczewski (6) reported Nigrospora as one genus among over 70 species of fungi isolated from cotton fibers from bolls from central Asia. Hansford (5) reported N. oryzae as one of many fungi isolated from the interior of cotton seed.

During the past 10 years N. oryzae has been sporadically found associated with a gray lint-rot of cotton in the San Joaquin Valley of California. A survey of cotton fields scattered throughout the northeastern San Joaquin Valley in early November, 1955, showed that Nigrospora rot was present in 12 of the 35 fields examined. Infected bolls ranged from a trace to as high as 10 percent of the open bolls present on the plants.

SYMPTOMS AND SIGNS

The lint in the affected locks (carpel contents) fails to fluff and is light-gray to almost black (Figure 1-A). At times only the base or the tip of the lint mass is affected and the remainder of the fibers fluff normally at maturity. Affected fibers are extremely weak and tend to break into small fragments under slight tension. By harvest time the diseased locks commonly have fallen from the boll or are easily dislodged when plants are jarred. For these reasons few of the severely damaged locks are harvested; however, partially invaded masses of lint were often present in cotton picked either by hand or by machine.

The dark color imparted to invaded lint is the result of heavy conidial production by the fungus. Individual conidia can be distinguished under low-power magnification by their extreme dark color as contrasted with the light colored mycelium and cotton fibers (Figure 1-B). Mycelium and conidia are produced throughout the invaded portion of the locks so that the internal color is also gray.

RELATION OF THE FUNGUS TO THE FIBERS

Microscopic examination showed that the mycelium of Nigrospora was present both in the lumen (Figure 1-C), and on the surface of the fibers. Conidia were produced abundantly from the surface mycelium, but also were found occasionally in the fiber lumen (Figure 1-D). The mycelium appeared to penetrate the cellulose fiber walls at random but often was concentrated in elongated strands in the lumen. The fiber walls were greatly weakened and tended to shred

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[1] Contribution from the California Agricultural Experiment Station, Davis, California, and Crops Research Division, Agricultural Research Service, United States Department of Agriculture.

[2] Plant Pathologist, California Agricultural Experiment Station, Davis, and Plant Pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Davis, California, respectively.

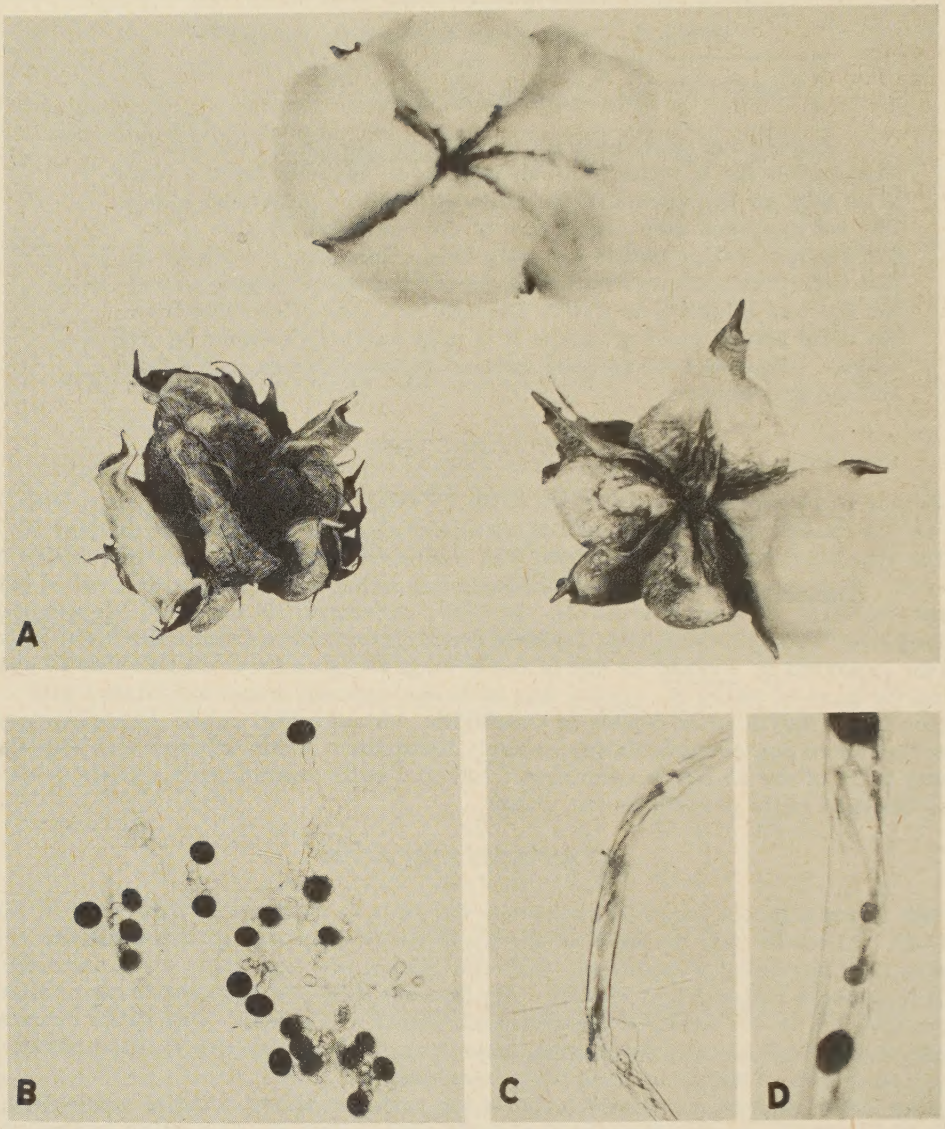

FIGURE 1. A -- Open bolls of Acala 4-42 cotton. Top: normal boll with fluffed fibers. Bottom: diseased locks showing complete and partial invasion by Nigrospora oryzae. B -- Typical conidia, conidiophores and mycelium of Nigrospora oryzae isolated from diseased cotton. Conidia average 15 μ in largest diameter. C -- Breaking and shredding of fiber wall at point of mycelial concentration. D -- Mycelium and conidia of N. oryzae in fiber lumen.

and break at such points of mycelial concentration. Typical N. oryzae was isolated from all parts of the invaded lint.

For study of the growth of the fungus on cotton fibers in culture, media were prepared by adding distilled water or inorganic salts of a basal medium to raw or processed and bleached lint. The media were sterilized by autoclaving and inoculated with N. oryzae. The fungus grew more abundantly on raw than on processed lint. The mycelium penetrated the fiber walls, but there was much less evidence of damage to the fiber strength and structure as compared with the damage shown by fibers from naturally infected bolls.

INOCULATION PROCEDURES AND RESULTS

Bolls of the variety Acala 4-42 were inoculated in the field by spraying a spore suspension of N. oryzae into the natural cracks along the carpel sutures as the boll approached the opening stage or by hypodermic injection of a spore suspension into the natural opening between the carpels at the "blossom end" of the boll about 5 days before such bolls would have opened naturally. Only 2 of 55 bolls sprayed with spore suspension developed lint-rot, whereas 78 of 110 bolls inoculated with a hypodermic needle showed typical lint-rot 3 weeks after inoculation. The number of locks affected in each boll varied from 1 to 5, with an average of 2.5.

Hypodermic inoculations of bolls of Acala 4-42 in the greenhouse at Davis, California, gave results similar to those in the field on bolls unopened at the time of inoculation. When cracked or partially opened bolls were inoculated in the greenhouse, lint-rot was very limited unless the bolls were subsequently either shaded or partially enclosed by a plastic covering. In either of the latter cases complete invasion of all locks usually resulted. Hypodermic inoculations into green bolls which had developed to half size or larger resulted in complete invasion of each lock inoculated. The fungus did not appear to penetrate the carpel walls and thus spread from one lock to another. Reisolations all yielded typical N. oryzae.

All evidence from inoculations indicates that the fungus must be introduced into the lint at a very early stage of boll opening, and during periods or in areas of high relative humidity in order to develop and produce the lint-rot.

This appears to be the first report of N. oryzae as a causal agent of lint-rot of cotton under field conditions in the United States of America.

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DEPARTMENT OF PLANT PATHOLOGY, UNIVERSITY OF CALIFORNIA, DAVIS